INTERNATIONAL STANDARD

ISO 7146-1

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Plain bearings — Appearance and characterization of damage to metallic hydrodynamic bearings —

Part 1: **General**

Paliers lisses — Aspect et caractérisation de l'endommagement des paliers métalliques à couche lubrifiante fluide —

Partie 1: Généralités

Reference number
ISO 7146-1:2008(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7146-1 was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 2, *Materials and lubricants, their properties, characteristics, test methods and testing conditions.*

This first edition of ISO 7146-1, together with ISO 7146-2, cancels and replaces ISO 7146:1993 the technical content of which has been technically revised and augmented.

ISO 7146 consists of the following parts, under the general title *Plain bearings — Appearance and characterization of damage to metallic hydrodynamic bearings*:

— *Part 1: General*

— *Part 2: Cavitation erosion and its countermeasures*

Introduction

In practice, damage to a bearing may often be the result of several mechanisms operating simultaneously. It is the complex combination of design, manufacture, assembly, operation, maintenance, and possible reconditioning which often causes difficulty in establishing the primary cause of damage.

In the event of extensive damage or destruction of the bearing, the evidence is likely to be lost, and it will then be impossible to identify how the damage came about.

In all cases, knowledge of the actual operating conditions of the assembly and the maintenance history is of the utmost importance.

The classification of bearing damage established in this part of ISO 7146 is based primarily upon the features visible on the running surfaces and elsewhere, and consideration of each aspect is required for reliable determination of the cause of bearing damage.

Since more than one process may cause similar effects on the running surface, a description of appearance alone is occasionally inadequate in determining the cause of damage. Thus Clause 4 is subdivided into several subclauses including damage appearance and damage characteristics.

For the procedure of damage analysis, Clause 5 may give a helpful guide.

In Clauses 6 and 7, examples of all damage characteristics with typically associated damage appearance are given.

Plain bearings — Appearance and characterization of damage to metallic hydrodynamic bearings —

Part 1: **General**

1 Scope

This part of ISO 7146 defines, describes and classifies the characteristics of damage occurring in service to hydrodynamically lubricated metallic plain bearings and journals. It assists in the understanding of the various characteristic forms of damage which may occur.

Consideration is restricted to damage characteristics which have a well-defined appearance and which can be attributed to particular damage causes with a high degree of certainty. Various appearances are illustrated with photographs and diagrams.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4378-1, *Plain bearings — Terms, definitions, classification and symbols — Part 1: Design, bearing materials and their properties*

ISO 4378-2, *Plain bearings — Terms, definitions, classification and symbols — Part 2: Friction and wear*

ISO 4378-3, *Plain bearings — Terms, definitions, classification and symbols — Part 3: Lubrication*

ISO 4378-4, *Plain bearings — Terms, definitions, classification and symbols — Part 4: Basic symbols*

ISO 7146-2, *Plain bearings — Appearance and characterization of damage to metallic hydrodynamic bearings — Part 2: Cavitation erosion and its countermeasures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4378-1, ISO 4378-2, ISO 4378-3, ISO 4378-4 and the following apply.

3.1
damage to plain bearings
bearing damage
all changes in appearance occurring on the bearing surface and/or on the bearing back during operation that adversely affect the performance of the bearing

4 Descriptions, causes, and features of damage

4.1 Damage

4.1.1 General

Damage to plain bearings is a phenomenon that adversely changes their tribological function, usually accompanied with a change in appearance. The damage is initiated by the damage cause and develops to the end of service life.

As long as no abnormal conditions occur, service life of the plain bearing relates to the service life of the machine.

4.1.2 Indicators of damage

Typical indicators observed during machine operation are: continuously increasing service temperature, decline of lubricant pressure, noise, vibration, and bad smell.

4.2 Damage causes

The cause is the practical event that initiates and leads to damage. The majority of damage causes will be found outside the bearing.

4.3 Damage appearances

Damage appearance is a defined visible picture of the bearing surface and/or of the bearing back. Damage appearances are clearly different from each other.

A plain bearing failure can show various damage appearances. Usually damage appearances are directly associated with damage characteristics, but not directly with the damage cause (for exceptions, see 6.8 and 6.9).

List of damage appearances:

a) depositions;

b) creep deformation;

c) deformation due to temperature cycles;

d) thermal cracks;

e) fatigue cracks;

f) material relief (loss of bond);

g) frictional corrosion;

h) melting out, seizure;

i) polishing, scoring;

j) traces of mixed lubrication, worn material;

k) blue, black colour;

l) corrosion, fluid erosion;

m) embedded particles, particle-migration tracks, formation of wire wool;

n) electric arc craters;

o) cavitation erosion appearance: worn-out material.

4.4 Damage characterization

4.4.1 General. A damage characterization is a description of what has happened based on a detected typical combination of damage appearances. Defined characteristics provide the basis for establishing the cause of damage.

Damage characterizations are clearly different from each other, as specified in 4.4.2 to 4.4.11.

4.4.2 Static overload: material is loaded above compressive yield strength corresponding to actual operation temperature.

4.4.3 Dynamic overload: material is loaded above fatigue strength corresponding to actual operation temperature. Intensive dynamic load also favours damage by weakening the fit.

4.4.4 Wear by friction: wear by friction is confined to changes in microgeometry and to the loss of material as a result of interaction between journal and bearing. Movement between backing and housing also favours wear by friction.

4.4.5 Overheating: the heat balance in the lubricant, the bearing, the environment, and the cooling system as required at design stage is not realized resulting in a higher temperature than anticipated. The viscosity and, therefore, the load capacity decrease with increasing temperature. This results again in temperature increase. The bearing, therefore, cannot operate stably if cooling cannot stop further temperature increase.

4.4.6 Insufficient lubrication (starvation): affecting the tribological system.

4.4.7 Contamination of lubricant with foreign particles or reaction products can result in damage to a bearing. Foreign particles embedded between bearing backing and housing also favour damage.

4.4.8 Cavitation erosion: decreased pressure in liquids leads to evaporation of liquids and formation of vapour bubbles, which, when liquid pressure increases, implode, generating locally very high pressure, and cause erosion on sliding surfaces.

4.4.9 Electroerosion: a potential difference between journal and bearing can lead to an electric arc with locally high current flow which damages journal and bearing surface.

4.4.10 Hydrogen diffusion: hydrogen may be incorporated in the steel backing or in an electroplated layer of the bearing. If hydrogen diffusion is blocked by a layer, blisters will occur.

4.4.11 Bond failure: delamination between lining and backing or between layers. A metallographic examination is required to distinguish from other damage characterizations.

4.5 Relationship between damage appearance and damage characterizations

Damage characterization and damage appearance alter with the progress of damage from a primary to a secondary characteristic (see Figure 1).

Different damage characterizations can correspond to the same damage appearance.

One damage characterization can correspond to various damage appearances.

Multiple damage characteristics can be found in one failure event.

The damage characteristics provide the basis for analysing the cause (see Figure 2).

Typical relationships are shown in Table 1 for damage to sliding surface and to bearing back. In most cases, Table 1 is the guideline for diagnosis of the final damage cause from the damage appearances via the damage characteristics.

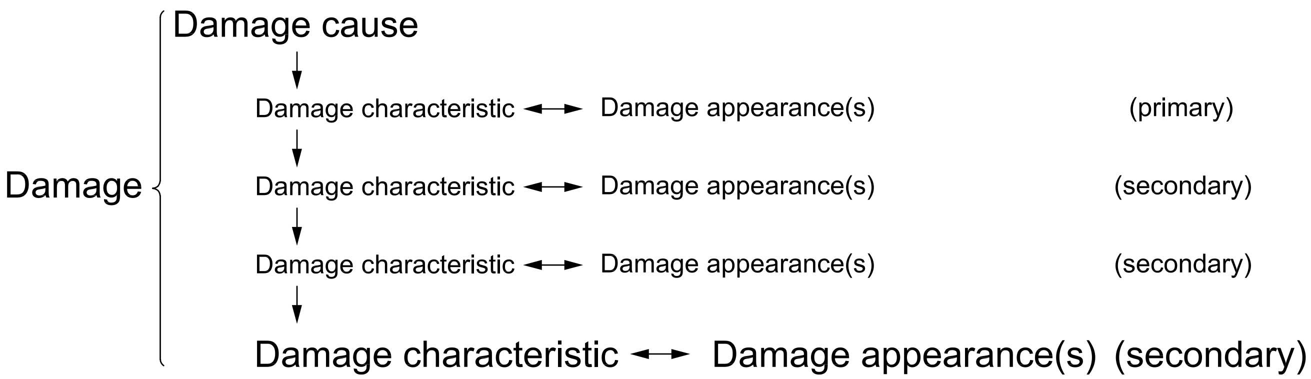
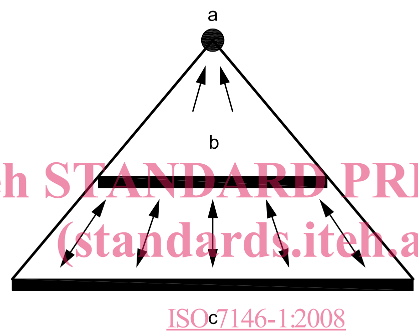


Figure 1 — Damage appearances alter with the progress from primary to secondary characteristics



a Damage cause.
b Damage characteristics.
c Damage appearances.

Figure 2 — Damage characteristics provide the basis for analysing the cause

5 Guidelines for damage analysis

Table 1 — Interaction of damage appearances and damage characterizations

Damage appearance																Damage characterizations	Subclause
Depositions	Creep deformation	Deformations due to temperature cycles	Thermal cracks	Fatigue cracks	Material relief (loss of bond)	Frictional corrosion	Melting out, scoring	Polishing, scoring	Trace of mixed lubrication, worn material	Blue, black colour	Corrosion	Fluid erosion	Embedded particles, particle-migration tracks, formation of wire wool	Electric arc craters	Cavitation erosion appearance: material worn out		
×	×		×						×							Static overload	6.2
				×	×											Dynamic overload [a]	6.3
				×		×										Dynamic overload [b]	7.2
								×	×							Wear by friction [a]	6.4
								×								Wear by friction [b]	7.3
×	×	×	×						×							Overheating	6.5
							×		×	×						Insufficient lubrication (starvation)	6.6
×								×	×		×	×	×			Contamination (particles, chemicals) [a]	6.7
×								×	×		×		×			Contamination (particles, chemicals) [b]	7.4
															×	Cavitation erosion	6.8 and ISO 7146-2
														×		Electro-erosion	6.9
					×											Hydrogen diffusion	6.10
					×											Bond failure	6.11

[a] Damage to the sliding surface.

[b] Damage to the bearing back.

5.1 General

Analysis should be undertaken only by experts experienced in bearing metallurgy, bearing technology and bearing damage. Damage analyses based on photos alone are mostly unsuccessful.

The following steps are a guideline for damage analysis.

5.2 Step 1

Establish service life. There is significant difference between damage after a short service life and damage after a long service life. With both cases similar damage appearances occur, but the cause is usually different.

Typical causes of damage after short service life: faults in geometry or assembling, dirt, effect from a previous damage, modified service conditions since last start up.

Typical cause of damage after long service life: modified service conditions.

Typical cause of damage after very long service life: reduced dynamic material capability due to fatigue.

5.3 Step 2

Strict differentiation between damage characterization and damage appearance is important. For a thorough analysis, all visible damage appearances shall be evaluated and combined in one or more damage characterizations, based on Table 1.

5.4 Step 3

Take into consideration the total system: bearing — shaft — lubricant — housing.

It is helpful to make a chemical analysis of a sample from the bearing layer and to check its microstructure. If necessary, lubricant and filter content should be analysed.

5.5 Step 4

All information in connection with the period before the detected damage and the period during the damage should be brought together.

5.6 Step 5

Reviewing the initial list of damage characteristics together with the information from steps 3 and 4 usually leads to a reduction of the number of damage characteristics under consideration. This will lead to the possible damage cause.

See Annex A for an example of use of Table 1.

6 Damage to the bearing surface — damage characteristics, typical damage appearances and possible damage causes

6.1 General

A discussion of damage to the bearing surface follows. For each damage characterization given in 4.4, typical damage appearances, possible damage causes and typical examples are given.

6.2 Static overload

6.2.1 Typical damage appearances

Creep deformation: shallow depressions of bearing material in the region of maximum load and temperature, beginning smooth and ending in crack-free semicircular bulges in the direction of rotation, sometimes like crests of waves (see Figure 3).

Traces of mixed lubrication (see Figure 4), depositions, thermal cracks.

6.2.2 Possible damage causes

Loading of the bearing was higher than that allowed for in the design and/or the bearing temperature was higher than estimated for an extended period.

6.2.3 Typical examples (see Figures 3 and 4)

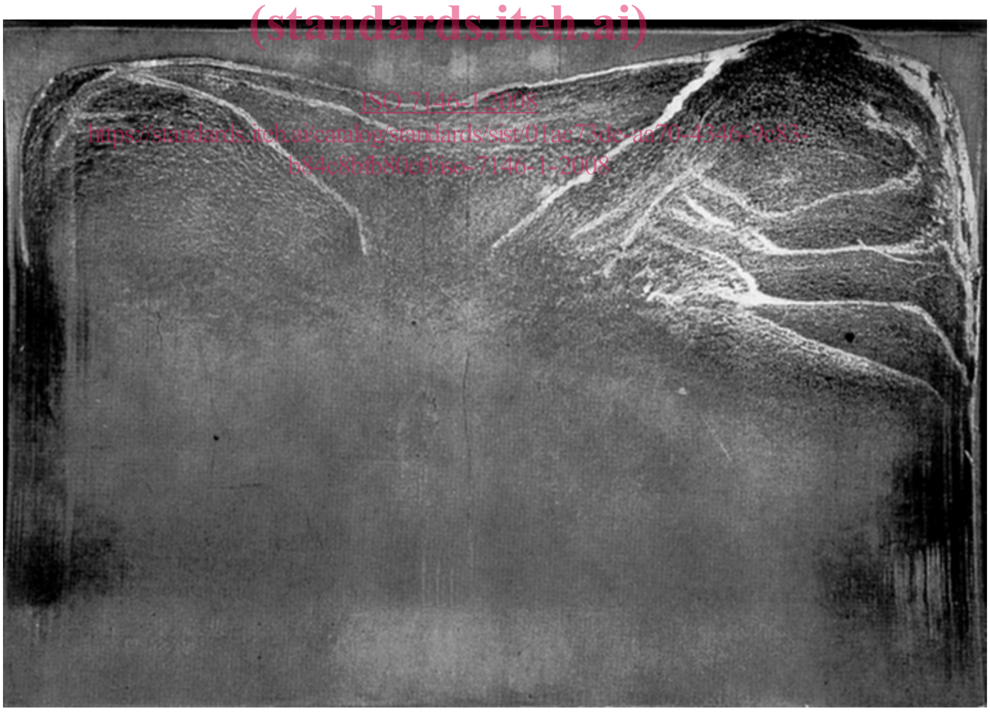


Figure 3 — Creep deformation, shown by crack-free semicircular bulges in the direction of rotation (material: steel/tin-based white metal)

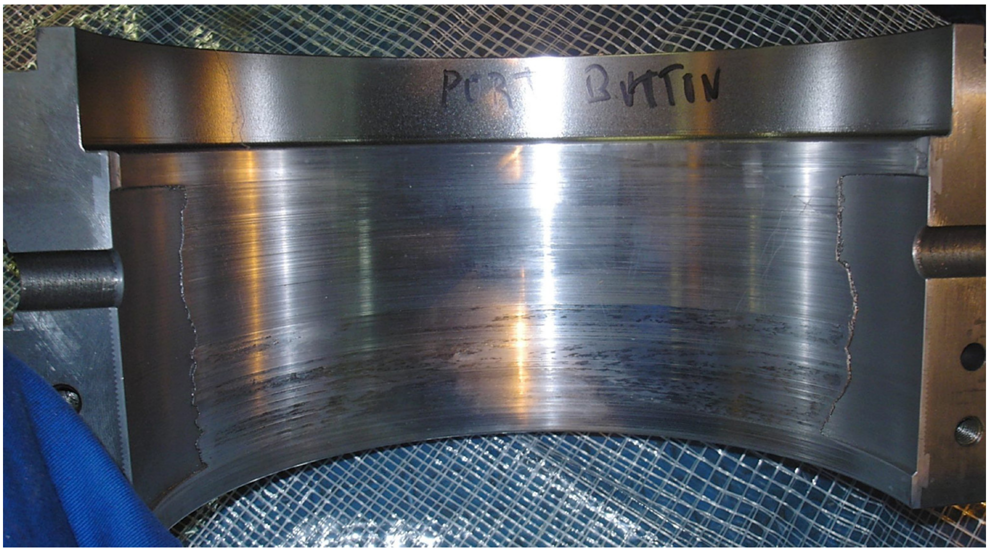


Figure 4 — Propeller shaft bearing, showing the effects of too slow a speed in relation to load capacity (material: steel/tin-based white metal)

6.3 Dynamic overload

6.3.1 Typical damage appearances

Fatigue cracks: Cracks which extend from the sliding surface in the loaded zone propagating as a network. The cracks change direction above the bonding area.

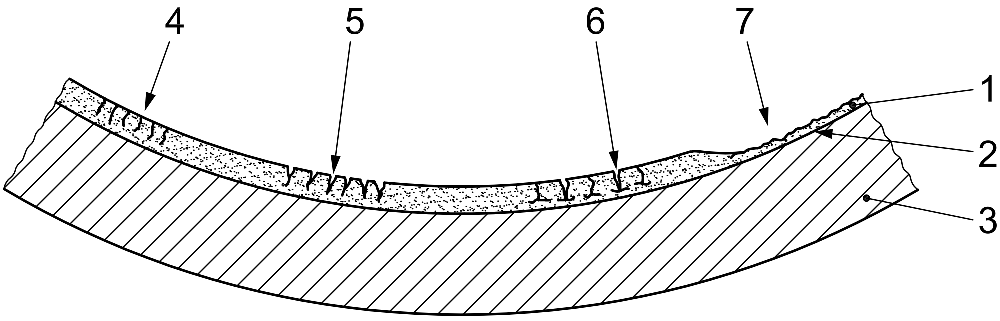
Lining material from the backing is the final result of the development of fatigue cracks (see Figure 5).

See also possible damage appearances such as frictional corrosion on the bearing back (7.1).

6.3.2 Possible damage causes

The cracks start when the fatigue limit of the bearing material is exceeded due to high dynamic load at the operating temperature. The damage is not based on bond faults.

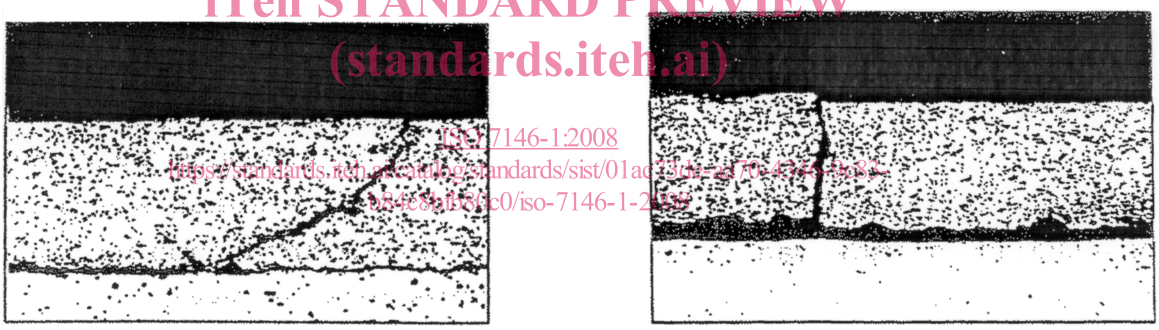
6.3.3 Typical examples (see Figures 5 to 12)



Key

1 lining material
2 bonding area
3 backing material
4 cracks
5 eroded cracks
6 cracks with perpendicular propagation
7 material relief

Figure 5 — Schematic diagram of progress of fatigue cracks



a) under inertial load **b) under gas load**

Figure 6 — Typical fatigue cracks of internal combustion engine bearing (material: steel/aluminium alloy)

